Impact of new technology on teaching and learning in technology education

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The paper commences by way of some general comments on the potential of technology in education. It recalls the characteristics of the early technologies, i.e. paper and printing press and post-war technologies, i.e. telephone, radio, photographic film, slides and audio recordings, overhead projector, film, video and mixed media and transmission through satellite networks. It examines the ever-growing interest and 'needs felt' to employ the 'new technology', for education in general and for technology education in particular. It briefly explains the transient concepts of mass education, individualised learning and group learning, which occurred in quick succession. Research findings on the effectiveness of different educational technologies are briefly stated in terms of the real benefits of technology in technology education.

The next part of the paper is devoted to examining the phenomena of learning, retention, recall and critical thinking from the point of view of behaviourist and cognitive psychologies and to look at the concepts of higher-order learning. An attempt is made to show how human learning curves improve with the infusion of educational technology and variety in learning. It is proposed to adopt a graphical observation form, which includes the effective use of educational technology for classroom activity analysis. Salient features of technology education in the context of design and technology are highlighted. An attempt is made to discuss the technology-propelled paradigm-shift and to identify the extent of software and hardware of technology required to create better learning through teaching-learning processes based upon new technology. Critical issues for evaluating the effectiveness of new technology are identified. Facts and figures on technology integration in the teaching-learning process are quoted from different parts of the world.

Finally, the paper dwells on the last decade of the turn of the millennium and the scenario with the onset of video conferencing, Internet conferencing, e-learning, etc. with regard to their outreach and relative effectiveness. Possible impact of the one-computer classroom is taken up to show how the availability of minimum infrastructure can be used in the developing world. Criteria for selection of appropriate technology is spelt out in some detail. A case is made for greater investment in staff development in the integration of new technology. The paper concludes by enumerating the ways in which the impact of new technology is made visible and by envisioning the not-so-distant future.

Keywords
education, technology, design, development, communications, learning, teaching

Introduction
You might have noticed that the word ‘technology’ occurs twice in the title of this paper – both as the cause and the effect. The first one refers to educational technology and the second is technology education. It follows that the word technology is going to be used repeatedly with techno-terms but I shall try not to ignore the words ‘teaching’ and ‘learning’; I propose to use them to limit my discussion to these areas of application.

A topic like 'Impact of New Technology on Teaching and Learning in Technology Education' occurs naturally to policy makers, who would like to see the positive correlation between improvement in education and technology costs, as in Curve A, Figure 1, before committing further investments. They would also like to see if smaller incremental costs in technology could bring about greater improvement in education as shown in Curve B. Let me clarify at the outset that educational improvements depend upon a multitude of factors including school setting, curriculum, staff development, management, students interest and of course, state of technology. Even the effectiveness of technology is a function of several variables that we shall discuss and there is no way an educationist can produce such graphs!

Figure 1: Expectations of policy makers.

The best we can do is to step back and ask ourselves some practical questions:

- can a new and emerging technology be reasonably evaluated in relation to improving teaching and learning processes? If so, how?
- can we create technology-based infrastructures for technology education? If so, how?
- can a new technology meet the new challenges of knowledge explosion and diverse learning
requirements to meet the ambitions of next-generation, knowledge-gobbling students and thus prove itself worthy of the expenditure?

As a matter of fact, policy decisions about future investment in technology should not be made by extrapolating the graphs of past performance, but on the basis of perceived potential of new technologies because several incredibly different, relatively inexpensive and connected technologies are fast emerging.

A look at publications during the last 30 years shows that ‘technology’ has always been referred to by phrases such as ‘poised for a giant leap forward’, ‘advancing exponentially’ and ‘with expanding frontiers’. (Unwin, 1969; Sakamoto, 1975; Lewis, 1988; Erant, 1980; Kozma, 2000) In that sense, technology has been the driver, manifesting itself in simple audiovisual resources, in video and televisions and lately as computer networks and the Internet, as shown by the donkey-cart analogy, Figure 2.

![Figure 2: Donkey-cart analogy of technology and education.](image)

**Educational technology development**

Hardware and software technologies for education have been emerging ever since the beginning of civilization in the Stone Age. Discovery of paper dates back to 105 AD in China, and the printing press to 1400 AD in Germany. The print medium has been around with us throughout the century and it continues to move on into the new millennium effortlessly (refer to Figure 3). Photographic film and slides owe their existence to the holidaymakers in Europe who subscribed to capture the beauty of nature. Both of them had their glorious days in education, bringing ‘the outside inside’. Telephone and radio, invented in 1920 and audio-recorders invented in the Forties, heralded the future of audio-based distance education. Invention of the Fresnel lens condenser in 1940 enabled the presenter to write on A-4 size acetate sheets for overhead projection. The onset of video and television in the fifties marked another era of audiovisual-based distance education.

<table>
<thead>
<tr>
<th>Global Communications</th>
<th>Desktop Computers</th>
<th>Programmed Instruction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Video Recordings</td>
<td>Closed Circuit TV</td>
<td>Transparancies</td>
</tr>
<tr>
<td>Radio Broadcast</td>
<td>Slides and Film</td>
<td>Print Matter</td>
</tr>
<tr>
<td>1900</td>
<td>20</td>
<td>40</td>
</tr>
</tbody>
</table>

**Figure 3: Development of educational technologies over the years.**

The popularity of the Video in the classroom was enhanced by a large number of video programmes on all subjects made throughout the world. For example, promotional videos (Kumar, 2000) on Video Script Writing, Video Power and Video Teleteaching, resulted in a multiplier effect in the developing world. The desktop computer, which emerged in late Fifties, led the way to different uses including computer-assisted, computer-managed and computer-mediated instruction, videoconferencing, networking and finally several Internet based technologies. Information technology can be viewed as ‘enabling technology’ to assist teachers to employ different sites for the tasks they may need to perform. For example, the Technology Magic and Worlds has created a site to explore 20-plus ways of using the Internet in teaching and learning. It lists click-on sites for different objectives such as visiting a museum in another country, finding up-to-date information on an invention, viewing current interviews on some projects and accessing data via online experiments. Likewise, Media Institute of Southern Africa (MISANET, 1991) has managed to do away with some isolation prevalent among African nations by enabling free flow of news and information across the continent. MISA has succeeded in hooking up media institutions throughout the Southern African Development Community (SADC) to the Internet. As of today, 29 newspapers and news agencies contribute to the MISANET news service.

A study of the world’s best web sites (Deek et al, 2000) shows that the cognitive characteristics of the best web designers are such that they are highly creative, risk-taking, imaginative and insightful individuals. While it is desirable to develop a web site to be rated high on content, design and special features, it may not be necessary to do so for educational purposes. For example (Kumar, 2001), interactive designs are made possible virtually without having a web site, merely by employing charitable URLs to launch specific designs, seeking all interested to participate...
online and offline and thus bring about design modifications through constructive criticism. The argument is similar to the fact that a mere chalkboard has served the classroom extremely well; simple Internet web sites can also be effective for learning.

In the US, satellite microwave transmission has been the most efficient and cost-effective method of providing continuous interactive learning in some sparsely populated areas of Alaska, Utah, Montana, the Dakotas and Arizona. In 1989, Northland Pioneer College in Arizona scheduled 16 courses via 2-way video systems and 19 courses via the network’s audio systems. In spite of technology related transmission problems, it overcame the dilemma of acute shortage of trained teachers.

Educational technologies developed in quick succession after the Second World War. Yet every new technology went through the phases of Research, Development and Use (Elton, 1977), Figure 4. The first major technologies, radio broadcast and closed circuit television, were considered capable of mass communication and hence extended to mass instruction, without understanding that the two are not the same thing. It was later realised that learning is individual to a learner. The focus changed to Individualised Learning with the pioneering contributions by Skinner in the area of Behavioural Psychology, based upon his stimulus and response theory and successive reinforcement. It led to the development of Programmed Learning with linear programming and branching programmed learning. It really gave birth to such ideas as 'preparing structured material', 'reinforcement', 'continuous evaluation', etc. which could not be exploited at that time due to lack of computing power.

Group Learning

Individualised Learning

Mass Instruction

1940  60  80  2000  10

Figure 4: Elton model of educational technologies.

Teaching machines looked bulky and scary, now given away to museums. Further realisation that teaching individuals in isolation of others deprived them of interactive learning, teamwork, collaboration, cooperation and competition, resulted in the next phase called group learning. Humanistic psychology played an important role in ushering in group dynamics with a variety of group interaction techniques such as game-playing, role-playing, simulations, case studies, group discussions, buzz sessions, etc. Change from mass instruction to group learning has led to a shift from hardware to software and from teacher centring to learner centring. The main features of educational technologies are tabulated below.

**Games and stimulation**
There has always been a scarcity of resources, more so in the developing world, and ‘effectiveness studies’ were conducted as soon as a new technology appeared. During the Eighties, in the advanced countries and during the Nineties in the developing world, there have been many research reports on the relative merits of different media. Far too many researchers have concluded that there is no significant difference between teaching/learning with different media. This is referred to as ‘no significant difference phenomenon’. A web resource shows several studies beyond the 355 similar research reports in the book (Russell, 1998). Such studies are not insignificant – as a matter of fact they are highly significant. They merely serve to show that there is no significant difference in the parameter being measured in comparing two methodologies and we can employ one or the other depending upon their favourable characteristics. For example, several studies, which show that different delivery systems make no significant difference in the learning gains, empower us to use the online methodology for distance learners in remote places without loss of learning potential.

Evaluation of online learning has been a subject of numerous researches by several authors including myself (Kumar, 1998 and 1999). Evidence from a study of the Sloan Centre for Asynchronous Learning Environment (SCALE) Efficiency Projects during 1997–98, shows that Asynchronous Learning Networks (ALN) achieved much higher
students/faculty ratios without impeding student learning. The study supports the view that when a sensible pedagogic approach is embraced that affords the students opportunity to communicate about their learning, ALN can produce real and tangible efficiency gains without sacrificing the quality of instruction.

The March Newsletter (Morrison, 2002) on the Technology Source Management has an interesting commentary on Web-based Course Management Tool to Support Face-to-Face Instruction. Tools such as WebCT, 'Blackboard', Virtual-U or 'LearningSpace' can be used either in the adjunct mode for web-enhanced instruction or in distance mode for online interaction. The advantage of the former, i.e. web-enhancement, include the following:

- allows instructor to capture class activities and archive the same, fully to enable students to access the course beyond the classroom
- permits and encourages students to contribute later through asynchronous communication
- encourages active learning through the use of just-in-time online resources and threaded discussion
- enables peer review and collaboration on group projects
- promotes learning through multiple forms of interaction distributed across space, time and different media.

An important feature of the above is the possibility of dual delivery by face-to-face and in distance mode. It overcomes the problem of redundancy of teacher effort by addressing both modes simultaneously. Systems like WebCT offer videoconferencing, online chat, student progress tracking, group project organisation, student self evaluation, grade maintenance, access control, navigation tools, auto-marked quizzes, course calendar, student homepages, student work areas, course content searches etc. Use of such features is seen to promote collaborative learning, enhance critical thinking and provide equal opportunity to all students to express their views. One really wonders what more to expect from educational technology to make teaching and learning in technology more meaningful!

A study on the effectiveness of a short course via the Internet (Kumar, 1999) based on comparing post-test and pre-test scores of a sizable random sample of participants showed that they gained by 61.7% with a standard deviation of 19.8%, which was significant at 0.05 level. Ratings on ten questions to evaluate the course on a five-point scale by the respondents revealed that they considered it worthwhile, instructive and appropriate to offer such courses to distant learners. Another study (Kumar, 1998) showed that faculty development workshops conducted through video teleteaching at seven centres in India resulted in significant 'pre-test to post-test' gains, recorded as 71.4% at 0.05 level of confidence. The participants were 'highly satisfied' and they recommended the holding of further courses via teleteaching. It can easily be concluded that technology offers the following:

- greater and faster access to more information
- varied ways of interaction and collaboration, face to face and at a distance
- ease of tracking students’ progress
- ease of remediation for struggling students
- more challenges to advanced students
- ease of interaction anytime and from anywhere.

We are, therefore, not propagating the use of technology in education just because everybody else is using it, e.g. in commerce, industry, public service, management, entertainment, networking, treatment and general communication. Thinking holistically, even that would have been a good reason because we are training students to go and assume responsible positions in the world of work.

Educational research
The story of educational research is as fascinating, if not more than that of technology development. The concept of knowledge has changed over the years from ‘something’ that can be transmitted or poured into the brains of the learners, Figure 5, to ‘something’ that can be taught and lately to ‘something’ that can be learnt, e.g. ability to think, design and create new ideas and things.

Figure 5: Students as receptacles of knowledge.

It all started with Thorndike, Pavlov, Watson and Hull in the early 20s trying to prove a connection between Stimulus and Response and they have come to be known as the S-R connectionists. Thorndike’s law of effect states that satisfaction serves to reinforce the S-R bond. His law of ‘trial and error’ learning has
become classical. Pavlov’s hypothesis of conditioned response sought to convert an unconditioned stimulus into a conditioned one. Gestalt psychologists introduced laws of organisation applying to perception and problem solving. Skinner made a mark by introducing structural stimulus and operant conditioning. Not being satisfied with extrinsic connections, Tolman, Locke and Piaget took up the study of cognitive processes, trying to conceive the brain functions and hence they have come to be known as cognitive theorists. Piaget developed a cognitive growth model of the development of intellectual ability of young learners. Gagne, primarily an associationist, has the distinction of evolving a criteria for good learning and corresponding methodology of good teaching. Bruner also worked towards evolving a theory of instruction and specified four features for such a theory, i.e. predisposition to learn, structure of knowledge, sequence of instruction and means of reinforcement. Ausubel introduced the concept of advance organisers, to increase the capacity of learners, likening the process of learning to building a structure! Some educational researchers over the years are shown in Figure 6.

![Cognitive Scientists](connectionists.png)

**Cognitive Scientists**
- Gagne
- Keller
- Ausubel, Bruner
- Bloom
- Skinner
- Piaget
- Connectionists
- Thorndike, Pavlov

| 1900 | 20 | 40 | 60 | 80 | 2000 | 20 |

Figure 6: A glimpse of educational researchers over the years.

Emerging from the theories of learning are the models of teaching such as the Inductive-Thinking Model by Hilda Taba; Inquiry Model by Schwab; Concept Attainment Model by Bruner; Cognitive Growth Model by Piaget; and Contingency Management Model by Skinner. Implementation of these models of teaching was facilitated by the contemporary development in technology and educational media.

The higher-order learning concept has been researched a great deal and higher order learning taxonomy has been proposed (Mustafa, 1997) for technology education. This was done in the context of authoring computer assisted learning packages to inculcate higher order learning. The hierarchical stages of higher order learning, proposed beyond the universally accepted levels of knowledge and comprehension due to Bloom, are comparing, inferring, integrating, problem solving and originating, each leading to a greater degree of mental processing and abstraction as shown in Figure 7.

![Higher Order Taxonomy](taxonomy.png)

![Taxonomy of higher-order learning.](taxonomy.png)

Comparing refers to distinguishing between two things or processes. Inferring is the cognitive process of making personal judgement on the basis of understanding facts and figures. Integration is the process of adding or assimilating in relation to existing cognitive structures. At this level, an individual is able to construct new meanings and holistic perceptions. Problem solving refers to the conceptualisation of discrepancy or incongruency of the desirable state from the given state and an attempt to finding alternative methods of overcoming it. Finally, originating is the highest level in higher order taxonomy, which involves displaying conviction characterised by pure, abstract and individualised reasoning. At this level, an individual should be able to provide original solutions to real and hypothetical problems.

The concept of learning curves of individuals, plotted as ‘rate of learning’ versus ‘passage of time’, Figure 8, during a learning session has gained renewed interest, now that the learning curves can actually be plotted, monitored and intervened for individual learners. It is observed that the attention span of learners is normally short as shown in curve A. Effective use of educational technology and variety in the teaching-learning process may trigger new restarts on the learning curve, as shown in curve B and thus increase the overall learning span of learners considerably.

![Learning Curves](learning-curves.png)

Figure 7: Taxonomy of higher-order learning.

Figure 8: Typical learning curves: effect of educational technology.
In an attempt to encourage teachers to use educational technology in their classroom teaching, a Teaching Observation Form similar to Flanders format was developed (Kumar, 1998) and used. By listing the observable points in three categories rather than two as in the Flanders, it is possible to record student activities, teacher activities and educational technologies employed with the passage of time. The resulting graphical display tells us the story of classroom interaction and technology utilisation as shown in Figure 9.

There has been a major paradigm shift in Education from the theories of ‘learning’ to theories of ‘cognition’. Cognitive science approaches teaching and learning by addressing how the human, as information processor, functions and uses information through higher-order thinking and problem-solving skills. Cognitive approach is important because it recognises human information processing strengths and weaknesses and limits of human perception and memory in coping with information explosion. It focuses instead on organising information to fit human capacity and it has changed the emphasis in education ‘from learning to thinking’. Technology has been making great impact on the nature of researches in the area of education. With the advent of newer technologies, most researches have been focused on the potential of technologies on learning and on the nature of learning itself. All these have lead to a multiple paradigm shift as summarised in Table 1.

Table 1: Paradigm shift in education by technology.

<table>
<thead>
<tr>
<th>Old Paradigm</th>
<th>New Paradigm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teaching is necessary for learners</td>
<td>Learning is possible by alternative methods</td>
</tr>
<tr>
<td>Ed. Technology: Self-learning Resources. e.g., Print matter, audio lessons, videos, media mix and multimedia</td>
<td></td>
</tr>
<tr>
<td>Students to enrol for available courses</td>
<td>Courses available on demand</td>
</tr>
<tr>
<td>Ed. Technology: Flexible learning: modular structures, computers, info kiosks and bulletin boards</td>
<td></td>
</tr>
<tr>
<td>Follow the academic calendar</td>
<td>All-time availability of courses for self-pacing</td>
</tr>
<tr>
<td>Ed. Technology: Video recordings, streaming video and Internet</td>
<td></td>
</tr>
<tr>
<td>University is a physical ‘place’</td>
<td>University is a virtual concept</td>
</tr>
<tr>
<td>Learning occurs in a classroom</td>
<td>Learning can occur ‘anywhere and any time’</td>
</tr>
<tr>
<td>Ed. Technology: Information technology, Internet Web sites, video conferencing, teleconferencing and e-learning</td>
<td></td>
</tr>
<tr>
<td>Single-discipline courses</td>
<td>Multi-discipline studies</td>
</tr>
<tr>
<td>Ed. Technology: Pick-n-choose software for flexible learning</td>
<td></td>
</tr>
<tr>
<td>Student as problem and problem maker</td>
<td>Students as valued customers</td>
</tr>
<tr>
<td>Ed. Technology: Students-centred learning resources</td>
<td></td>
</tr>
<tr>
<td>Teacher-centred methods of teaching</td>
<td>Interaction and student-centre learning</td>
</tr>
<tr>
<td>Ed. Technology: Learning resource centres, Smart-classrooms with multimedia and, projection facilities</td>
<td></td>
</tr>
<tr>
<td>Books are the primary resource</td>
<td>Multitude of alternative resources</td>
</tr>
<tr>
<td>Ed. Technology: Alternative technologies, microfilm, microfiche, CD ROM and the Internet</td>
<td></td>
</tr>
<tr>
<td>Students in 18-25 age group</td>
<td>‘Cradle-to-grave’ learning</td>
</tr>
<tr>
<td>Ed. Technology: Open learning technologies</td>
<td></td>
</tr>
<tr>
<td>Technology is an option</td>
<td>Technology is necessary and desirable</td>
</tr>
<tr>
<td>Ed. Technology: Optimisation technologies and multimedia</td>
<td></td>
</tr>
<tr>
<td>Learning for the sake of examination</td>
<td>Learning for critical thinking &amp; creativity</td>
</tr>
<tr>
<td>Ed. Technology: Question banks, Internet resources for discussion groups</td>
<td></td>
</tr>
</tbody>
</table>

Figure 9: Classroom activity and interaction observation form.
Nature of technology education in design and technology

Education in the area of technology has many things in common with all other areas, e.g. science and arts, but technology is characterised by human ability to think creatively and to apply practical and mechanical sciences. It refers to hardware and software aspects of materials, processing, measurement, manufacturing, information technology, computer aided tasks and testing. Science and technology are neither the same thing, nor close enough to be clubbed together for teaching the same way. Science refers to the generation of knowledge, i.e. laws, principles, etc. from the observation of natural phenomena. On the contrary, design relates to conceptualising new artefacts, i.e. hardware and software, and technology is concerned with the creation of the same for the benefit of mankind. Knowledge of science stands in good stead so that we do not attempt to violate the laws of science but apply them meaningfully as depicted in Figure 10. Technology for design (Norman, 2000) is defined as the ‘summation of knowledge, skills and values’ to realise designs. For that matter, again, technology is seen to be independent of science. Norman has stressed the point of ‘teaching by showing and learning by doing’ for technology capability.

<table>
<thead>
<tr>
<th>Design</th>
<th>Using Knowledge and Tools</th>
<th>Employing Processes and Products</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Conceiving 3-D Nature</td>
<td>Making Things Happen</td>
</tr>
<tr>
<td></td>
<td>Perceiving Order and Pattern</td>
<td>Making and Realising</td>
</tr>
<tr>
<td></td>
<td>Communicating Variousliy</td>
<td>Using Hardware and Software</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(Fact Finding, Explaining Phenomena, Hypothetising, Formulating Laws and Expanding the Frontiers of Knowledge, etc. …)</td>
</tr>
</tbody>
</table>

Figure 10: Activities of science, design and technology.

In the UK, the first Order for technology was issued in March 1990 following the Report on Technology in the National Curriculum, (DES, 1990) and the subject ‘design and technology’ was launched into schools. The Revised Order (DES/WO, 1992) reaffirmed the merits of the subject. This is as far as the design and technology subject is concerned at the school level. Technology courses have been in existence at the university level for a very long time.

<table>
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<td>(Fact Finding, Explaining Phenomena, Hypothetising, Formulating Laws and Expanding the Frontiers of Knowledge, etc. …)</td>
</tr>
</tbody>
</table>

Botswana is the only country in Africa, where design and technology has been taught in junior and senior secondary schools since 1989. New curricula have been published and implemented for Botswana General Certificate of Secondary Education with effect from 2000. The subject entitled ‘technology’ includes energy, structures, mechanisms, electronics and pneumatics, whereas tools and processes cover measuring and marking out, saws and sawing, planes and planing, files and filing, drills and drilling, chisels and chiselling, shears and shearing, joining and fabrication, assembling tools and finishing processes. I may add that the University of Botswana started preparing teachers for design and technology with effect from the year, 1990. The syllabus for the university students was prepared to match with the then school requirement. Consequently, the design and technology teachers, who were inadequately trained, have not been effective in teaching the subject and making a mark at schools. The university curricula have since been revised to become science-based curricula with a full year of foundation courses in science subjects, not provided before. Simultaneously, the university is considering a proposal to offer a parallel industrial design programme to train students in different aspects of designing and technological processes for the world of work.

In South Africa, the subject of technology has been introduced by the Western Cape Education Department in their schools. The curriculum covers technology capability, including process skills, graphical communication, structures, materials processing, systems and controls, tools and equipments, biases and planning in technology. In essence, the curriculum is very close to the subject of design and technology in Botswana. The Netherlands curriculum in ‘Technology, for 15+’ formulated in 1993 (Cor de Beurs), attempts to integrate technology with existing science subjects and by admitting design methodology and skills in the same. Design modules have been made in physics, chemistry and biology. In spite of the fact that design does not appear in the title of the course, it constitutes a major component.

Technology education refers to educating children to employ the hardware and software of technology. It includes educating theory and practice of a range of material processes for metal, wood, plastics materials and, more recently, textile, leather and food materials. All these areas have a component of learning theory but the greater and more important component is that of gaining practical experience. Finally, students are required to demonstrate their practical competence by way of composite projects in design and technology. They should, therefore, be able to plan, select materials, processes, instruments, etc., and make and test products. Interestingly, there have been some studies on teachers’ attitudes to educational technologies. The one from Texas (Knezek, 1998) conducted on 250 teachers from six schools showed that responses of teachers varied significantly in respect of email learning, semantic perception of computers and of the world wide web. It was noticed
that the schools with high-speed access had better perceptions and more positive attitudes to the use of educational technology. Teachers from all schools opined positively about the index of computer productivity in the classroom.

Curricula in technology education have been revised to keep pace with advances in technology. For example, computer aided design and manufacture CAD/CAM, three-dimensional sketch modelling and rapid prototyping are some of the recent additions – as is the introduction of food and textile technologies. Fortunately, computer aided design software, e.g. AutoCAD 2000 package, are self sufficient with built-in educational technologies.

Critical issues for evaluating effectiveness

The US Secretary’s Conference on Educational Technology (NCET, 1999) identified several critical issues in evaluating the effectiveness of technology, summarised as follows:

• That the effectiveness of technology is embedded in the effectiveness of other school improvement efforts. Examples of such efforts are classroom administration, teachers’ pedagogical skills, and student preparedness.

• That the current practices for evaluating the impact of technology in education need broadening. This is intended by evaluating technology implementation efforts, curriculum integration methods, harnessing the new learning opportunities for students and employing newer instruments of measurement of the attributes of effectiveness of technology.

• That standardised test scores offer limited formative information with which to drive the development of a school’s technology programme. Formative evaluation of technology is more important than the summative evaluation because it is the formative evaluation, which gives an insight into student’s motivation, attitudinal changes learning styles students’ capability to handle more complex assignments and projects and progress profiles.

• That schools must document and report their evaluation findings in ways that satisfy diverse stakeholders’ need to know. This is because interest in the effectiveness of technology is at an all time high for the government, for the taxpayer, parents, teachers, students and above all, the policy makers. For example, the policy-makers are interested in overall summative evaluation of technology-related grants while the educators are more concerned with the formative assessment of technology-added environment in their curricula. It is also important to report the evaluation to different target groups differently, to the extent of their technology-literacy and computer literacy skills.

• That in order to provide stakeholders with answers to their questions about the effectiveness of technology in education, everyone must agree on a common language and standards of practice for measuring how schools achieve that end. For example, we should develop additional tools to measure whether students are learning better about basic teamwork skills, lifelong learning skills, etc., which are often claimed to be true without adequately substantiating the findings. It is not just the institutions; stakeholders must also suggest the types of tools that would satisfy them in their questions. There are things teachers and students can now do through the assistance of technology that they could not perform before. Such possibilities show the impact of technology. For example, it is now possible to map out a student’s learning effort, quantify the time and quality of his/her interaction with others across the Internet and closely monitor his/her progress, which were not possible without technology.

• That the role of the teacher is crucial in evaluating the effectiveness of technology in schools, but the burden of proof is not solely theirs. All said and done about student centring and self-learning, teachers remain to be most intimately concerned with the details of the means of bringing about learning of students. The teacher’s work has become more demanding in terms of searching for more information on the Internet, observing students accessing and using information. Teachers are the first to notice a behavioural change in students and to see them grow in self-esteem, confidence and enhanced learning in comparison to what they would have achieved without technology. Teachers are the first to feel the impact of technology on their student’s learning. Teachers are, therefore, integral to the process of evaluating technology initiatives by becoming partners with researchers and suggesting ways and means of measuring the learning outcomes of students and recording key indicators of effectiveness of technology.

Technology integration: some facts and figures

I would like to cite some facts and figures from the literature, which support the claim of positive impact of educational technologies:

• Educators in Iowa State used Bloom’s taxonomy of cognitive learning as a guide to observing technology-integrated learning units. Significantly, they noticed that technology-integrated learning reached higher in Bloom’s hierarchy than non-technology-integrated learning.

• A study at West Virginia demonstrated by isolating the effect of educational technology
from other factors that ‘the more the access to technology, the higher the students scored in standardised tests’.

- A four-year study focused on eight specific goals was used to evaluate the impact of the investment in the state of Idaho. It showed significant academic gains as measured by the Iowa Test of Basic Skills (ITBS) and the Test for Academic Proficiency (TAP) for 8th and 11th graders.
- Children encouraged to employ technology as a tool in their learning became literate, co-operative, problem solving and self-motivated learners, faster than otherwise at Mantua Elementary School in Virginia.
- A technology-rich environment resulted in measurable reforms in education for higher–order thinking and collaboration skills at the Union City School, New Jersey.
- Enrolment in Chemistry classes swelled by nearly 500% when technology was integrated into the ninth-grade science curriculum at the East Brunswick Public Schools in New Jersey.
- Teachers using the Internet put in more details and more illustrative resources into their lesson plans at the Montgomery, Alabama.
- A count in several districts in the US showed that interdisciplinary instruction was more prevalent in technology-supported institutions.
- It was noticed in Anderson County Schools in Tennessee, that teachers were dependent upon computer connectivity more than anything else, in their teaching. They called off their classes when servers were down!
- Students who used technology in their coursework scored 15% higher than those who did not use technology at the Blackfoot School District, Idaho.
- Teachers' capacity to evaluate students learning with and without technology is being relied upon at a number of institutions including California, Montana and Washington States.
- Students of all six remote schools in Arizona, where Internet services were provided to access libraries, used them more than students in other schools where libraries were located in the same towns. It also turned these schools to open schools, now being used by other learners across the state.
- Reviews of implementations and benefits of the school-wide use of computer technology in five pioneering technology-rich schools and four reviews of experimental data on the use of computer technology in order to implement a familiar curriculum component; all nine of them (Melmed, 1995) showed a positive correlation between ‘extent of the use of technology’ and degree of ‘students knowledge generated’.

**Impact of one-computer classroom**

It is generally lamented in the developing world that technology cannot make a meaningful impact because computers are in short supply. This is in not necessarily true. One computer per classroom can also make an impact, if employed with care. There are a large number of studies on one-computer classrooms. Research shows that just one computer can be used to advantage for classroom teaching and post-class activities. The computer can be used in conjunction with smart chalkboard to project graphics to show skills to conduct virtual visits, to play video clips, and to keep records and to monitor the progress of each student in a class. Projection may be achieved with LCD display panels placed over overhead projectors or with data projection systems. The computer can be used as a flip chart to write the points in a brainstorming session or to access the Internet anytime and even to publish the work on a web site! Students may use the computer in small groups as a cooperative learning tool after the class hours. It is, therefore, important to note that inadequacy of computers in classrooms does not seriously hamper innovative instructional techniques. Shortage of computers, which is being viewed as a handicap in developing countries, may actually be a blessing in disguise in the sense that it is forcing group learning and collaborative learning, which are superior to individual learning. A review of several studies and a sustained study in the Indian context (Kapur, 1997), shows that computer aided learning environment is more effective than in terms of the achievement scores of students, when compared to the print material in the individual mode and more so in the collaborative group learning mode. It was also pointed out that that there was no significant difference in the achievement of members studying in groups of two or three. However, studies on groups of four or more students using the same computer show that the learning gains drop significantly in comparison with groups of three students. Good practices to integrate technology in education include the following:

- effective use of software, i.e. to match the learning goals of students
- extensive use of Internet to access web sites via search engines and gateways
- student grouping to achieve collaborative and cooperative learning
- student controls to enable learners to manage their own learning
- use of content-specific technologies, e.g. simulation for more difficult, expensive and risky real-life situations
- use of technology to assist learning by objectives as a seamless part of the lesson
Selection of cost effective technologies
Studies on the effectiveness of educational technology must take into account the following factors:

- the learning goals to which it is applied
- the relationship between learning goals and the curriculum
- the capability of staff to meet the challenge of applying technology
- the support by the school management to meet the goals
- the capability of students to employ the technology
- the likely achievement of students in relation to the goals.

In a growing multitude of alternative technologies, it is necessary to identify the most ‘cost effective’ means of providing quality education and training to students. A dynamic criteria (Bates, 1995) with the acronym ACTIONS, recommended for decision makers, consists of analysing the answers to the following questions by the organisation concerned:

Selection Criteria: Questions for the Criteria

- **A** Access? How accessible is the particular technology?
- **C** Cost? How affordable is it per unit learner?
- **T** Teaching /Learning? Does it support the teaching/learning required?
- **I** Interactivity? Does it enable user-friendly interaction?
- **O** Organisation? Would the organisation support it?
- **N** Novelty? Is it a relatively new and emerging technology?
- **S** Speed? How fast can it be adapted for courses?

The topmost criterion is accessibility at place of work, at home, at other places, at different time of the day and with minimal effort and equipment. If a technology is not easily accessible, it may as well be left alone. The cost of technology is another strong discriminator between technologies. However, cost per student study hour drops off drastically with the number of students enrolled.

Several other educationists have also identified the variables for technology selection. For example, a Technology Effectiveness Workshop, 1995, resulted in recognising the following six variables, which are similar to Bates’ criteria.

2. Operability: open architecture and transparency.
3. Location and direction of resources.
4. Capacity to engage students for challenging tasks.
5. Ease of use: user friendliness, training and support.
6. Functionality: preparation of learners for diverse functions, development of skills for programming and skills for project design and implementation.

Staff development: a master key
If there is one single parameter which influences the effectiveness of technology in education, it is the teacher’s preparedness and enthusiasm to use technology. In a report to the US Government, the Business Week correspondent, Grossman pointed out that ‘the Government is spending $2 billion a year to connect every classroom to the Internet but we spend virtually nothing on the content. So when they connect to the Internet, the uses of it for educational purposes are extremely limited. And certainly, the training of teachers is virtually non existent’. What then, is required to prepare and to enthuse teachers? Preparation of teachers requires a well-planned and on-going staff development programme with highly motivated resource persons both in the areas of technology and education. Teachers would then learn not only how to use new technology but also how to provide meaningful instructional activities using technology in the classroom and beyond it. Teachers need in-depth, sustained assistance in using technology and in their effort to integrate technology into the curriculum. Skills training becomes peripheral to alternative forms of on-going support that addresses a range of issues, including changing teaching-learning practices for the paradigm shift, changing assessment practices and all such tasks which create the impact of technology in education.

Besides pedagogical support to help students use technology to reach learning goals, teachers also need time to become familiar with available products, software and online resources. They also need to discuss the uses of technology with other teachers and collaborate with them in order to create a multiplier effect. Simultaneously, it is important to make structural changes in the school day by allowing teachers time to collaborate and work with their students and bring about engaged learning. The problem is no longer going to be ‘not enough computers but not enough time’ to incorporate technology into their instruction. Teachers need to be able to do the following:

- specify the purpose of using technology in relation to educational goals, i.e. to support inquiry, to enhance communication, to access global resources, to analyse data, enable product development or monitor their progress and select the appropriate technology
- coordinate technology implementation efforts with core learning objectives
- collaborate with colleagues for instructional design and students’ learning experiences
• encourage students to broaden their horizons with technology and to use different software
• ensure that students learn to collaborate and value the constructive comments and criticism of others
• use alternative assessment strategies, including standardised tests
• promote students to prepare electronic portfolios of their work.

Once the staff members undergo some training by way of attending workshops, it is possible to update themselves by becoming a member of one of several mailing groups in the area.

(Morrison, 2002 and Butcher, 2002)

Conclusion

The impact of educational technology in technology education is manifold. The impact is indeed visible in terms of following outcomes:

• greater effectiveness, in terms of time and cost savings, of the classroom teaching-learning processes
• greater motivation and satisfaction of students to learn with a variety of technologies
• greater reach out to students who would otherwise not be able to study
• effective mid-career retraining of personnel to be able to change jobs
• global access, communication and multiple interaction online and offline and self-management.
• new possibilities of monitoring students, individual progress, extent of interaction, study styles, etc. which are not possible without technology
• technology enhanced tasks for multidisciplinary studies, removal of barriers between subject and disciplines, which were otherwise adversely affecting education
• paradigm shift by way of evolving new roles of teachers and students. Students to explore for themselves as cognitive apprentices and teachers to be facilitators and change agents.

The future of educational technology may be envisioned by the following perceptions:

• more and more students will have access to information technology, both inside and outside the classroom
• teachers will increasingly use instructional technology including the Internet in their teaching-learning activities in different modes of teaching
• computer professionals will shape the next generation of technology applications for education, guided by research and development efforts by the faculty.

It is, therefore in our interest to gear ourselves to the emerging scenario. If we don’t catch up, we shall be replaced by buttons! It is time to wake up to technology to its fullest utilisation throughout the globe.

References

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